Power Density Measurements in the Near Field of the DSS 13 26-Meter Antenna

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Power density measurements were made at DSS 13 in the near field of the 26-m antenna to determine if radio frequency (rf) fields generated by the 20-kW transmitters could be responsible for the failure of three solid state (FET) rf amplifiers. These amplifiers are used in the SETI Radio Spectrum Surveillance System, which is currently located at the site. Measurements were made independently for one transmitter at 2115 MHz, one at 7150 MHz, and both transmitters together. Measurement results are tabulated and compared with predicted power densities under the measurement conditions. The results agree with predictions within a factor of two; the predictions appear to give "worst case" values. Measurements indicated that amplifier failures are not attributable to the transmitter.

I. Introduction

One of the field test activities for the Search for Extraterrestrial Intelligence (SETI) project at Goldstone involves the use of a Radio Spectrum Surveillance System (RSSS) to survey and characterize the radio frequency interference in the band from 1 to 10 GHz. Shortly after the initial survey was under way, three of the seven radio frequency (rf) amplifiers in the system failed at nearly the same time. Discussions with the manufacturer raised questions about potential damage from rf fields produced by the transmitters on the 26-m antenna, which is located a few hundred meters away. A plan to measure the rf fields at the SETI RSSS location was developed and carried out in July 1986.

Concern about mutual interference among co-located transmitting and receiving systems at the DSN complexes is clearly not unique to SETI.[1] The Planetary Radar Transmitter at DSS 14 is known to interfere with reception at DSS 15, which is located just 350 meters away. When transmitting near 8500 MHz, the radar interferes with VLBI data systems at the Mojave Base Station, which is located some 10 km away.

This article documents the measurements that were made and compares the results with expected levels based on calculations of rf field strengths in the near field of the 26-m antenna at DSS 13. Similar measurements were performed in 1970 on a 64-meter antenna [1].

[1] "RFI Analysis Final Report," ER 81-18, produced by Ford Aerospace under JPL Contract 956094, December 7, 1981.

II. Background

The SETI RSSS [2] is a scanning spectrometer with the capacity to step through a sequence of seven contiguous rf bands from 1 to 10 GHz. The system is equipped with a 0.91-meter-diameter parabolic antenna that can be stepped in azimuth under computer control. The elevation angle can be set manually and locked into position. The antenna is fed with a linearly polarized pyramidal log-periodic feed.

The system was installed in a van located 288 meters east of the DSS-13 26-m antenna (see Fig. 1). The antenna assembly, mounted on top of the van, is approximately 19 meters below the intersection of the azimuth and elevation axes of the 26-m antenna.

The 26-m antenna is equipped with transmitters at 2115 MHz and at 7150 MHz. Both transmitters, each with a nominal power output of 20 kW, can be radiating at the same time. A safety interlock system prevents transmitter operation when the antenna is tipped to elevation angles of less than 10 degrees.

As a result of altitude differences in the local terrain and the 10-degree elevation interlock, the rf axis of the main beam of the 26-m antenna, when transmitting, will always be at least 13 degrees above the RSSS antenna. Therefore, only off-axis responses of the 26-m antenna pattern would radiate power into the RSSS antenna. It is these power levels that were measured during the experiment.

III. Measurements

A Hewlett-Packard 436A Digital Power Meter was used to measure the detected power levels at the output of the RSSS antenna (Fig. 2). The power meter was equipped with a wideband detector (HP 8484A) which is sensitive from 10 MHz to 18 GHz. The RSSS antenna was pointed directly at the 26-m antenna, while the latter, within the elevation interlock limitation, was incrementally positioned to maximize the detected output of the power meter. The measurement procedure was independently performed for the two transmitters. The peak detected power levels and the corresponding 26-m antenna pointing angles were recorded.

The power density value at the input of the RSSS antenna can be derived from the detected power levels if the effective area of the receiving antenna is known. The effective area of an antenna, expressed in square meters, is given by the expression

$$A_e = \frac{g\lambda^2}{4\pi} \tag{1}$$

where g is the antenna gain and λ is the wavelength of the transmitted signal. The gain of the RSSS antenna is 23.4 dBi at 2115 MHz and 30.7 dBi at 7150 MHz. Power density S, in watts per square meter, is given by the expression

$$S = \frac{k(p)P}{A_e} \tag{2}$$

where $k(p)$ is the polarization factor, P is the measured power, and A_e is calculated from Eq. (1) for each wavelength. For this measurement, $k(p) = 2$ to account for the fact that the transmitter feeds are circularly polarized and the RSSS antenna is linearly polarized.

The results of the measurements and subsequent calculations are summarized in Table 1.

IV. Discussion

It is useful to compare the measured power densities with the predicted values that can be calculated for the near field of the 26-m antenna. D. A. Bathker (private communication) has estimated that the antenna gain, approximately 13 degrees off axis in the near field, should be about 3 dB above isotropic (dBi). For this estimate, the diffraction at the edge of the subreflector is estimated to be –6 dB. The on-axis gain of the common aperture (multi-frequency) feed horn is +22 dBi, and the illumination taper of the subreflector is –13 dB. Bathker estimates that the residual +3 dBi is distributed within the zone some 13 to 18 degrees off axis.

The power density $S(r)$, in watts per square meter, at distance r from the transmitting antenna is given by the expression

$$S(r) = \frac{P_t G}{4\pi r^2} \tag{3}$$

where $P(t)$ is the transmitter power (20 kW) and G is the numerical value of the off-axis antenna gain described above ($G = 2$ for the 3 dBi). According to Eq. (3), the power density for either frequency at the RSSS antenna, located in the near field at distance $r = 288$ meters, should be approximately 0.038 W/m^2. Note that this value is independent of frequency.

V. Conclusions

The measured values of the power density agree, within a factor of two, with the estimated value of 0.038 W/m^2. The measured values at both frequencies fall below the estimate, which can be considered to be a "worst case" prediction. This result supports the validity of the power density estimates in the near field of the 26-m antenna at DSS 13.

The results of these measurements further suggest that the amplifier failures were not induced by the rf fields from the 26-m transmitters. Both measured and predicted power levels were far below the maximum in-band tolerance (+20 dBm) specified by the amplifier manufacturer. Subsequent tests of the FET amplifiers by the manufacturer confirmed this conclusion.

These results do suggest, however, that care should be taken if bipolar transistors are used in second or succeeding stages of rf amplification. Power feedthrough from first (and succeeding) FET stages could damage the bipolar transistors if the unit is subjected to rf fields similar to those measured in this study.

References

[1] D. A. Bathker, "Predicted and Measured Power Density Description of a Large Ground Microwave System," TM 33-433, Jet Propulsion Laboratory, Pasadena, California, April 15, 1971.

[2] B. Crow, A. Lokshin, M. Marina, and L. Chin, "SETI Radio Spectrum Surveillance System," *TDA Progress Report 42-82*, vol. April–June 1985, Jet Propulsion Laboratory, Pasadena, California, pp. 173–184, August 15, 1985.

Table 1. Results of power density measurements at DSS 13

Parameters	2115-MHz transmitter 20 kW	7150-MHz transmitter 20 kW	Both transmitters on
Maximum detected power	+5.0 dBm 3.16 mW	+4.1 dBm 2.57 mW	+9.2 dBm 8.32 mW
26-m antenna position			
Azimuth angle	92.176 deg	92.620 deg	92.343 deg
Elevation angle	11.502 deg	11.547 deg	11.547 deg
RSSS antenna effective area	0.350 m^2	0.165 m^2	
Power density input to RSSS antenna	0.018 W/m^2	0.031 W/m^2	

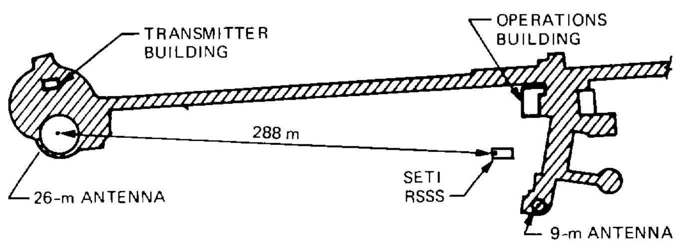

Fig. 1. Location of SETI RSSS on the Venus station

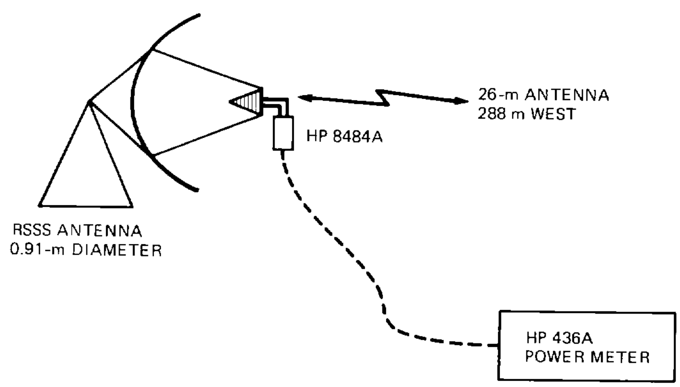

Fig. 2. Power density measurements for the 26-meter antenna